CHAPTER SEVEN

Bringing the Environment Back In

A Transnational History of Landsat

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In the spring of 1976, as the US government made preparations to celebrate the country's bicentennial during the upcoming July Fourth holiday, the United Nations published the quarterly report of the Mekong Committee. Although the committee had originated back in 1957 to promote the development of Southeast Asia's lower Mekong River basin through large-scale dams and irrigation projects, this particular report publicized scientific data captured by orbiting satellites developed by the National Aeronautics and Space Administration (NASA). To make this scientific information more legible, the report included a full-page map of parts of Laos, Cambodia, Thailand, and Vietnam that was overlaid with ten orbital tracks of one of NASA's satellites (see fig. 7.1). "Landsat-II imagery is showing important new information," explained the report, adding that this particular Earth-observing satellite had collected more than 160 "frames" of data as it circled high above the 230,000-square-mile region between September 1975 and January of the following year. This valuable scientific work, assured the report's conclusion, "is continuing."[1]

The Mekong Committee's *Landsat* map also shows how technologies and the scientific knowledge they help to create, while often initiated nationally, in this case within the United States, almost always travel far beyond national borders. The map of the lower Mekong basin, for instance, illustrates not only the movement of space technology across the political boundaries of Southeast Asia but also the circulation of scientific

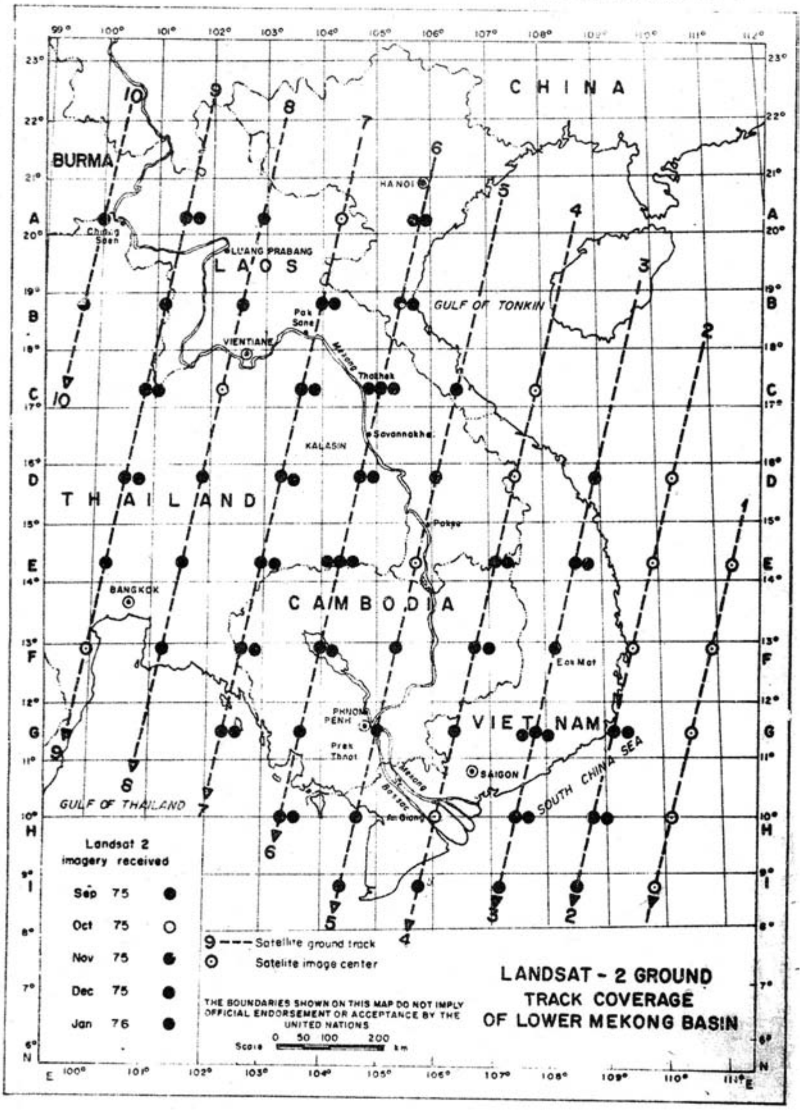

FIGURE 7.1. Map depicting the orbital track coverage of *Landsat 2* over the lower Mekong River basin from September 1975 through January 1976.
Source: Courtesy of National Aeronautics and Space Administration.

knowledge; the small, empty circles on the map represent "satellite image centers" that received and processed data on the ground in South Vietnam, Cambodia, Thailand, and Laos. This UN map thus neatly displays the novel framework of this collection of essays, which analyzes national governments and state agencies as actors, often quite powerful ones, functioning within dispersed international networks that both produce and circulate technologies and scientific knowledge. Rather than erasing the nation-state, the Mekong Committee's map, much like this collection, places it within its transnational context.

The satellite map and the Mekong Committee's overall report, however, also identify another important historical agent that is often missing from the current historiography on transnational technoscience. Far below *Landsat 2*, which orbited more than five hundred miles above Earth, flowed the Mekong River. While the UN map represents the waterway with a double line winding its way from Burma in the north to the southern tip of Vietnam, the body text of the report focuses entirely on the basin's natural environment. The publication explained that the *Landsat* data collected by the Mekong Committee would be used to analyze the basin's hydrology, especially with respect to flooding, to differentiate between different forest types, such as evergreen, deciduous, and mangrove, and to identify a wide variety of land use practices from rice farming to rubber tree plantations. "The main objective of the Mekong Committee investigations using Landsat data," explained the introduction to the report, was to collect scientific information that could be used to map "agricultural crops and land use, and for soil moisture monitoring."[2] As this full-page illustration suggests, technology and science do not operate alone on the transnational stage. Rather, they interact with, and most often seek information about, the natural world.[3]

Although historians of transnational science and technology have shied away from incorporating nature into their analyses, environmental historians have for decades been analyzing how nation-states explore and extract natural resources within their borders, as well as how federal governments regulate such land use and enact legislation to correct environmental problems.[4] This state-centered approach served early practitioners well. However, as environmental historian Donald Worster explained in his seminal 1982 essay "World without Borders: The Internationalizing of Environmental History," "the nation-state is no longer a suitable framework." The field's future success, Worster predicted, "will be found in research that moves easily across national borders." Environmental historians have followed Worster's advice, tracking various natures, whether they be flowing water, wafting pollution, or migrating animals, weeds, and diseases, across political boundaries.[5] This transnational approach, Worster concluded more than three decades ago, "calls for the reformulation of our research, so that when we find our Walden Pond to study we will also have found the River Ganges."[6]

The present chapter treats the Mekong River basin, as well as other natural environments beyond the United States, as important historical actors within the transnational history of science and technology during the twentieth century. I use the history of NASA's *Landsat* satellites as a case study to analyze how a technology developed within the United States became a hub that bound together a thick transnational network of space and ground communications systems, international and national agencies, American corporations and NASA, as well as indigenous engineers, technicians, and scientists attempting to better understand, and control, the natural environment. In the process, *Landsat* became a mechanism for both American hegemony and limited local control within the developing world.

I begin by examining not only the development of *Landsat* technology in America but also several of the impediments that limited the technology's success abroad. Installing ground stations in remote regions of foreign countries was sometimes dangerous; foreign researchers had to learn how to use the data and images provided by American satellites and computers; and government officials across the developing world were also concerned that the orbiting technology would infringe upon their countries' national sovereignty. To overcome these problems, the US government in the early 1970s began "selling" *Landsat* across Asia, Africa, and Latin America. In the end, although local knowledge about various natural environments situated within their own nation-states gave indigenous scientists and government officials a modicum of power regarding *Landsat*, the satellite's thick transnational network allowed the US government to maintain ultimate control over both the space technology and the scientific knowledge it produced. In other words, asymmetries in technology, scientific knowledge, and political power, although masked, were never fully effaced, even though NASA claimed otherwise.

Engineers and scientists at NASA could proudly claim, quite correctly, that their *Landsat* satellite was "made in America." This was because the technology, which the space agency first launched on July 23, 1972, was initially developed from both military hardware such as the *CORONA* spy satellite and civilian technology used clandestinely for war, including the *TIROS* and *ATS* satellites. Such top-secret origins precluded international cooperation on *Landsat*, which circled 560 miles above Earth in near-polar orbit taking 13,000-square-mile "snapshots" of the planet's surface.[7] During the next quarter century, six additional *Landsat* satellites gathered data for millions of images of planet Earth. By radioing back "pictures" of Earth from space, the *New York Times* explained in mid-January 1975, *Landsat* was "providing new insight into man's continuing effort to better manage earth's limited resources as well as aiding in the assessment and understanding of environmental changes."[8]

This thoroughly American technology included multispectral scanners that measured from space four different wavelengths of electromagnetic radiation reflecting off objects on the surface of Earth. Originally, *Landsat* satellites beamed these wavelength measurements back down to NASA's receiving stations in Fairbanks, Alaska, in Goldstone, California, and at the Goddard Space Flight Center in Greenbelt, Maryland. In each of these locations, technicians converted the raw data into visual maps by assigning coded false colors to Earth-bound objects with different wavelengths. *Landsat*, in other words, made the natural environment more legible by measuring the extremely slight temperature variations of the solar heat bouncing off rocks, trees, water, and even animals.[9] As *Science* magazine reported on the tenth anniversary of *Landsat 1*, the maps created from the Earth-observing satellite depicted "scarlet forests, red patchwork farms, blue city grids, brown crinkled mountains, and a delicate web of highways."[10]

Landsat's colorful maps quickly became scientific tools for analyzing natural resources, and NASA immediately began promoting such capabilities through easy-to-read pamphlets and booklets with appealing titles such as *Improving Our Environment*, *Ecological Surveys from Space*, and *Photography from Space to Help Solve Problems on Earth*. According to these publications, *Landsat* satellites aided agriculture and forestry by making possible the inventory of different types of crops and trees, the identification of early signs of plant diseases and insects, and the assessment of soil moisture to guide future land use practices. The space technology proved equally beneficial for the study of hydrological and atmospheric resources; *Landsat* data mapped fresh and salt water, forecast droughts and floods, and identified sources of both water and air pollution. It also provided geological measurements that located underground resources, including oil, natural gas, and mineral deposits, and even allowed biologists to track migratory wildlife both across the land and under the seas.[11]

By helping to manage natural resources, *Landsat* was also helping to manage NASA's public image, which during the early 1970s was suffering on the domestic front from a severe case of "NASA fatigue." As the *Los Angeles Times* put it in April 1972, "A long mental yawn will roll over America next Sunday when Apollo 16 spits fire from its tail and streaks skyward to the moon."[12] Partly because of such apathy, between the Moon landing of 1969 and the launch of Apollo-Soyuz in 1975 Congress drastically cut the space agency's funding. All told, during this six-year period beginning after Apollo 11, the federal government slashed NASA's budget by more than 40 percent, after accounting for inflation, to its lowest real-dollar level since 1962.[13]

In a conscious effort to reverse this trend, NASA administrators began publicizing to the American public *Landsat*'s role in scientifically assessing natural resources located within the United States. From 1972 to 1974 this entailed the development of the Large Area Crop Inventory Experiment, or LACIE. The joint venture by NASA, the Department of Agriculture, and the National Oceanic and Atmospheric Administration (NOAA) combined crop acreage measurements obtained from *Landsat* with meteorological information from NOAA satellites to forecast wheat production in an effort to stabilize the commodity's price for American consumers.[14] Such publicity efforts by NASA succeeded; not only did Congress authorize two additional *Landsat* satellites in 1975 and 1978, but it also increased the space agency's budget by more than 10 percent, after accounting for inflation, between 1975 and 1980.[15]

President Richard Nixon quickly realized that *Landsat* could do for the United States internationally what it had done for NASA domestically. Early on he understood *Landsat*'s promotional potential and announced in September 1969 to the UN's General Assembly that America's new Earth-observing satellites would "produce information not only for the U.S., but also for the world community."[16] Space agency officials were even more explicit, focusing many of their public comments concerning productive uses of *Landsat* data specifically on the natural resources of poorer countries. The new space technology would "assist both the developed and developing areas of the world alike in providing maps and other important resource inventory data," explained a

NASA position paper on remote sensing. In doing so, the report went on to argue, "the use of remote sensors in NASA spacecraft to aid developing countries thus represents an important way for the United States to enhance its world image."[17] By giving poor nations access to scientific data that could help them better manage their own natural resources, *Landsat* technology could raise the international standing of the United States by helping developing countries develop.

There were just two problems with this rosy scenario. First, at least initially, several developing nations openly resisted NASA's remote-sensing technology for fear that it would infringe upon their national sovereignty. While the Soviet Union was concerned that *Landsat* could be used for spying, countries across Latin America were more worried that developed countries would employ the technology to exploit natural resources located in the developing world; wealthier nations such as the United States could use satellite data not only to identify previously undiscovered resources, such as mineral and oil deposits, within poorer countries but also to forecast global crop production in an effort to manipulate agricultural commodity prices.[18] To protect against such actions, in 1975 several developing nations, including Argentina, Chile, Venezuela, and Mexico, cosponsored an unsuccessful UN proposal that would have prohibited any remote-sensing activity relating to natural resources under a country's national jurisdiction without prior consent from the nation being remotely sensed from space.[19]

The second problem hindering the US government's desire to promote *Landsat* globally was that scientists in developing countries were not trained in how to use the data being captured by NASA's satellites to assess their own country's resources. Such was the conclusion of an exasperated Verl Wilmarth, one of NASA's Earth observation managers, who during the summer of 1971 lamented the quality of proposals submitted by foreign scientists interested in participating in future *Landsat* experiments. The "poorly prepared proposals," he wrote, "indicate lack of knowledge of the program content and capabilities."[20] Administrators at NASA were equally concerned that even if foreign scientists did eventually understand *Landsat*'s capabilities, they would nevertheless continue to lack the technological and scientific expertise necessary to take full advantage of the new space technology. Of particular concern was the dearth in developing countries of trained photointerpreters both to analyze the images obtained from satellites and to extract from them the types of data with economic value.[21] To build a transnational network of knowledge producers and users, the space agency thus not only had to convince leaders of developing countries that *Landsat* did not pose a threat to their national sovereignty but also had to educate foreign scientists regarding the space technology's scientific and economic benefits for their own countries.

Government officials and NASA administrators started addressing such problems in the early 1970s. They began by inundating the international scientific community with press releases describing how *Landsat* technology worked. They also called for proposals from foreign scientists themselves that would improve natural resource management specifically in developing countries.[22] The space agency then augmented such efforts by teaming up with international institutions such as the UN, the World Bank, and the Inter-American Development Bank to sponsor conferences, symposiums, and workshops, some up to two weeks long, on the scientific uses of *Landsat* remote-sensing data.[23] Initially, the space agency invited foreign scientists, engineers, and politicians to such events held in the United States, both at academic institutions such as the University of Michigan and also at NASA's research facilities, including the Johnson Space Center in Houston, which conducted a week-long "Earth Resources Survey Symposium" during the summer of 1975. At the Houston *Landsat* conference some of NASA's heavy hitters, including Apollo astronaut Russell Schweickart, Marshall Space Flight Center director Wernher von Braun, and Johnson Space Center director Chris Kraft, addressed an audience of more than 1,200 scientists, engineers, politicians, and administrators from at least two dozen foreign countries on the practical applications of Earth-observing technology.[24]

During the mid-1970s NASA administrators and the US government also brought these educational training opportunities directly to foreign scientists and government leaders within developing nations. During the summer of 1975, for instance, the space agency conducted several three-day symposiums on Earth-observing technology in West Africa. They sought both to educate scientists and government officials in the region about the capabilities of *Landsat* technology and to encourage them to submit scientific proposals aimed at better managing their countries' scarce natural resources. The very first of these conferences, held in Ghana for English-speaking participants, was attended by scientists, engineers, and government leaders from that country as well as from several other nearby nations, including Nigeria, Liberia, and Togo. They listened, along with US ambassador to Ghana and former child movie star

Shirley Temple Black, as the keynote speaker implored those present to make use of "accelerating tools" such as *Landsat* in order to bridge the "technological gap" between underdeveloped and developed nations and propel the former along the arc of modernization (see fig. 7.2).[25] During the 1970s similar NASA conferences promoting the benefits of *Landsat* technology for developing countries took place in Asia and throughout Latin America.[26]

While NASA's conferences, workshops, and symposiums helped to educate participants from developing nations regarding *Landsat*'s scientific usefulness, the space agency simultaneously tried to alleviate con-

SYMPOSIUM – Dr. A. N. Tackie, Executive Chairman, Council for Scientific and Industrial Research, Ghana, addresses members of the Earth Resources symposium in Accra. Seated behind Tackie is the U.S. Ambassador Shirley Temple Black. To the right of Black is the U.S. Information Service Director, Ed Pancoast; and E. Lartyte, Director of the Ghana Institute of Industrial Research.

FIGURE 7.2. Dr. A. N. Tackie, executive chairman of Ghana's Council for Scientific and Industrial Research, addressing attendees of NASA's Earth resources symposium. Seated third from right is US ambassador to Ghana Shirley Temple Black.
Source: Courtesy of National Aeronautics and Space Administration.

cerns regarding the technology's encroachment on national sovereignty by training foreign scientists to collect, analyze, and interpret Earth observation data on their own. As with its *Landsat* conferences, such training took place both within the United States and abroad. In the early 1970s, for example, NASA expanded its international fellowship program to encourage foreign scientists to travel to American universities to take courses on the fundamentals of remote sensing.[27] The space agency also brought scientists from developing countries such as Brazil and Mexico to NASA centers, including the Johnson Space Center, to familiarize them with the acquisition, processing, and analysis of remote-sensing data.[28]

In an effort to institutionalize such training within these less developed nations, NASA, along with the US government, encouraged political leaders around the world to create their own remote-sensing departments, to train their own photointerpreters to assess remote-sensing data, and to establish their own national committees to determine for themselves the best applications and distribution of remote-sensing information.[29] Perhaps most important, the US government urged these developing nations to establish their own *Landsat* receiving stations to collect data on their country's natural resources. In South America this process began in 1974 when Brazil built its own receiving station, and continued three years later when Chile signed an agreement to build another and Venezuela formally expressed interest in doing the same. By early 1977 Egypt and Iran in the Middle East and Zaire in Africa had also established their own stations to receive and process *Landsat* data (see fig. 7.3). Each of these host countries funded, owned, and operated their *Landsat* ground stations, making their scientific experiments less dependent on the United States.[30]

Such efforts by NASA, both to educate the international scientific community about *Landsat* and to alleviate concerns of foreign government officials regarding the technology's impact on national sovereignty, proved enormously successful. The conferees at NASA's symposium in Ghana, according to one participant, were "openly receptive in their response to prospective remote sensing programs in their respective countries."[31] Participants across the developing world seemed to agree; by 1977 more than fifty countries worldwide were relying on *Landsat* data to better manage their natural resources.[32] "The benefits of this new capability promise to be particularly significant in the developing countries of the world," explained *Science* magazine in the mid-

FIGURE 7.3. Map depicting the coverage area in Africa for the *Landsat* ground receiving station planned for Zaire.
Source: Courtesy of National Aeronautics and Space Administration.

1970s, because they "lack other means of surveying and assessing their resources."[33]

Across Asia many scientists used *Landsat* to map, for the very first time, the natural resources of their countries. In Burma, for instance, local scientists used NASA's multispectral scanners to delineate two-dozen categories of land types, such as wetland, grassland, and barren land, and also different land uses, such as agriculture and forestry. Scientists undertook similar studies in India and Bangladesh.[34] Throughout Africa such efforts tended to focus instead on improving the continent's food supplies. *Landsat* data allowed biologists from Sudan to inventory land, vegetation, and soil resources, game managers from Kenya to administer more efficiently rangeland for both domestic and wild animals, and hydrologists from Botswana to assess their country's only perennially flowing waterway, the Okavango River, for possible agricultural development.[35] Finally, in Latin America, local scientists from Bolivia, Venezuela, Colombia, Chile, and Argentina relied on remote-sensing data to locate mineral deposits, estimate water availability in arid regions, and produce the first accurate maps for large portions of the continent.[36]

While *Landsat* data helped scientists from the developing world to assess their local environment, nature on the ground in these countries was in turn influencing how *Landsat* data was being used. This was most evident during so-called "natural disasters" that struck several developing nations during the early to mid-1970s.[37] One such event was the severe and prolonged drought during the early 1970s that parched the Sahel region of Africa and caused widespread famine across the northern portion of the content. Scientists and government officials in Mali, one of the hardest-hit countries, responded by submitting a proposal to NASA to host a "Sahelian Zone Remote Sensing Seminar and Workshop," which was held in April 1973 and attended by more than thirty scientists and project managers from nine West African countries.[38] As a direct result of the training, local scientists used *Landsat* data to track the deteriorating impact of sand and dust storms on Sahelian plant communities and soil fertility as well as to determine range management techniques that could reverse the process of desertification.[39]

In Latin America the natural environment played a somewhat different, yet equally active role. This became obvious in July 1975 when an unexpected frost destroyed more than 80 percent of the trees in one of Brazil's most productive coffee-growing regions. In this case the extreme weather spurred local agronomists to lobby Brazil's space agency, the Instituto de Pesquisas Espaciais, to capture *Landsat* data for the region to study the frost's ecological effects.[40] Additional unexpected natural phenomena—from earthquakes in Nicaragua, to floods in Pakistan, to volcanic eruptions in Guatemala—also spurred local scientists in the developing world to submit proposals to NASA that resulted in novel uses of *Landsat* data.[41]

Although these natural disasters gave indigenous scientists and technicians some control over *Landsat* data, their experiences in the field also highlighted the significant social impediments to forging such transnational technological networks. In Brazil, for example, technicians analyzing satellite data constantly lacked supplies and replacement equipment, which had to come from the United States. They also had to overcome opposition from military officers who were concerned about the aerial surveillance of strategic sites, convince politicians to relax prohibitive laws that restricted natural resource exploration, and educate and train potential users of remote-sensing data from other government agencies in the art of photointerpretation. "It's hard to run a high technology effort in Brazil," admitted one scientist involved in the country's remote-sensing program. A reporter from *Science* agreed, noting in 1977 that such social obstacles on the ground in Brazil illustrate quite clearly "what is often involved in introducing a novel technology in a developing country."[42]

Which finally brings us back full circle to Southeast Asia and the Mekong Committee's quarterly report of 1976. During the committee's *Landsat* experiments, local scientists and government officials from the four countries straddling the Mekong River basin—Laos, Cambodia, Thailand, and South Vietnam—used NASA's satellite data to create three natural resource maps. The first, which was a land use map that differentiated between agricultural and forestlands as well as among different types of crops and tree species, was intended to help government officials from these developing countries better understand their current natural resource practices. The second map, which assessed the region's "land capabilities," was essentially a soil atlas aimed at improving planning for future natural resource management.[43] Together this pair of maps illustrate not only the physical movement of *Landsat* technology across national borders but also the complicated process of producing and circulating scientific knowledge through transnational networks composed of unequal partners.

The final map in the series demonstrates the often-forgotten role played by the natural environment in this transnational partnership. Back in 1966 the lower Mekong basin experienced the largest flood on record up to that time; 82 percent of cultivated land in the Vientiane plain in Laos became inundated, and some areas remained submerged under three to four meters of water for nearly one month. The Mekong Committee responded by investigating ways to address this environmental crisis. "The devastating flood of the Mekong River which occurred in September 1966," explained the committee's annual report, "served to emphasize the need for flood protection and control."[44] In the early 1970s *Landsat* offered a solution, and the committee encouraged local scientists and government officials from the basin to use remote-sensing data to map annual flood and drainage patterns in the Mekong lowlands. The result was the Mekong Committee's third map, a hydrological survey of basin flooding during different times of the year. Here in Southeast Asia it was flooding, rather than African drought or Brazilian frost, that influenced *Landsat* and its network.

Although all three of these *Landsat* maps were, as the Mekong Committee argued, "urgently needed in order to finalize a realistic post-war development program for the basin," NASA's remote-sensing technology was ultimately more of a mixed blessing for the inhabitants of the developing world, including those in Laos, Cambodia, Thailand, and South Vietnam.[45] On the one hand, *Landsat* measurements of natural resources from Botswana to Brazil to Burma depended on the cooperation of local scientists and politicians for success; biologists on the ground knew best which of their country's natural resources needed study from space, while native government officials had the political and economic capital to construct receiving stations and train photointerpreters. *Landsat*'s focus on local nature, in other words, left room for local control over *Landsat*'s scientific data.[46]

Yet the US government, in cooperation with NASA, still fabricated and launched *Landsat* satellites, decided when they should be "turned on" over what geographic regions, and determined which countries could and could not participate in the program. Administrators at NASA, sometimes guided by federal bureaus such as the Department of Defense, even had the power to demand that proposals by foreign scientists for *Landsat* experiments be "negotiated," or revised, before being officially approved.[47] As a result, while politicians and scientists from developing countries embraced Earth-observing programs in part because they could influence them from below, the American government ultimately controlled this modernizing project from above in ways that almost always supported its own foreign policy agenda and served the needs of military intelligence. When it came to the construction and maintenance of *Landsat*'s transnational network, in other words, the centralized political power of Washington, DC, trumped the peripheral influence of scientists in the developing world.

This foreign policy predicament for citizens of Asia, Africa, and Latin America had taken root soon after World War II, when American scientific and government elites worked together to rebuild research and development in war-ravaged Europe. While European technicians understandably welcomed such efforts, just as scientists and government leaders from developing countries welcomed *Landsat*, by sharing in this scientific diplomacy they ultimately helped to coproduce it and were thus less able to oppose more objectionable US foreign policy initiatives. *Landsat* functioned similarly by enhancing America's soft power across the developing world.[48]

Such was the case regarding NASA's involvement with the Mekong Committee in Southeast Asia, which began in 1973 as US troops starting leaving Vietnam. By enlisting *Landsat* to help the four countries straddling the basin to better manage their natural resources, the US government and the space agency ceded some control over the project to local government and scientific officials. To verify the accuracy of *Landsat* data, NASA technicians had to compare it both with aerial photographs provided by government administrators in Laos, Cambodia, Thailand, and South Vietnam and with field observations made by indigenous scientists from local forestry, agriculture, and other natural resources agencies. The "short term objectives" of the lower Mekong River basin *Landsat* experiment, explained NASA's Frederick Gordon, who oversaw the project from the Goddard Space Flight Center in Greenbelt, Maryland, were "supported by ground truth data and field surveys" and with "aerial photographs made available by the national departments" in the basin's four riparian countries.[49] The land use, soil, and flood maps of the basin created three years later from NASA's *Landsat* data were thus also coproduced, a joint effort by both the space agency and locals on the ground in Southeast Asia.

Yet this joint effort was not between equals. The overwhelming ability of NASA and the US government to direct the Mekong Committee's *Landsat* project in ways that supported American foreign policy was quite apparent in the quarterly report from April 1976, which the space agency coauthored. Although NASA officials completed the report more than six months after the fall of Saigon to communist forces, these adminstrators, perhaps wishfully, referred in the text to the nation of "South Viet-Nam" even though the country no longer functioned. American interests were likewise front and center in the full-page *Landsat* map accompanying the report (see fig. 7.1). The illustration by NASA, which superimposed the ten orbital tracks of the satellite over a political map of the region's national borders, refrained from identifying the soon-to-be reunited country by its official name, the Socialist Republic of Vietnam, and also included, quite prominently, a dotted line for the demilitarized zone that until quite recently had divided North from South Vietnam near the 17th parallel.[50] Additionally, while NASA did not "turn off" *Landsat* over Vietnam when the country became reunited in 1976, the US government's decision to ban assistance to the victorious communist government essentially halted the Mekong Committee's remote-sensing program.[51]

The history of *Landsat*'s promotion and use during the mid-1970s in developing countries, including those devastated by the war in Vietnam, illustrates important lessons regarding the transnational history of technology and science in the twentieth century. Too often historians have focused their sights solely on technology and science as it circulates both within nations and across the borders that divide them. In doing so they have ignored unruly nature as well as the enormous work involved in trying to tame it. The second lesson is that such work is almost always coproduced. Native scientists and engineers strove to weave together transnational networks, composed of government officials, local agencies, NASA, and the US government, that created, maintained, and circulated scientific knowledge on how to better manage their countries' natural resources. The space agency provided this scientific information from above while helping to train locals on the ground to process and use this data to assess their own crops, forests, deserts, and even their own national borders.

Indigenous nature situated within the developing world, whether it be infamous floods and frosts or more mundane crops, trees, and minerals, gave local scientists and government leaders the ability to influence, to a degree, *Landsat* technology and the scientific information it created. The result was reduced anxieties on the local level regarding *Landsat*'s potential to threaten national sovereignty. However, such national autonomy was always constrained by the asymmetrical power relationships that shaped this network, even though NASA constantly downplayed such inequalities. On the domestic front, an international community of *Landsat* users helped enhance NASA's public image and secure an increase in the agency's budget. Internationally, NASA was necessarily engaged in the US government's global ambitions and could build or break this technoscientific network at a moment's notice by denying access to *Landsat*.

Nature was the material that bound together this transnational community of *Landsat* users. It still does, just as the natural environment continues to connect networks of communities relying on technology and science in our twenty-first-century world. Our current climate change crisis is merely the most pressing example. Environmental history brings this natural world—which is often disorderly, fragile, and exploited—back into the history of science and technology, not as a passive stage on which this history plays out, but rather as an actor that shapes human behavior and the ultimate trajectory of social change. When studying such events beyond the national framework, therefore, historians must remember to place both technology and science in their environmental, as well as transnational, contexts.

Notes

1. Mekong Committee Secretariat, Mr. W. J. van der Oord and Mr. Frederick Gordon, Technical Monitor, Goddard Space Flight Center, "Agriculture/ Forestry Hydrology," 5a, Quarterly Report, Dec. 1975–Feb. 1976, Mekong Committee Secretariat, c/o ESCAP Sala Santitham, Bangkok, Thailand, dated Apr. 1, 1976, NASA Technical Reports Server, Document ID 19760016569, Accession ID 76N23657, report no. E76-10330, NASA-CR-147211, REPT-2.

2. Ibid., 1.

3. The terms "nature" and "environment" are historically complex. On the difficulty of defining "nature," see Raymond Williams, *Keywords: A Vocabulary of Culture and Society* (New York: Oxford University Press, 1976), 184–189. The notion that material nature is embedded within culture and therefore also socially constructed is widely accepted within the field of environmental history and was initially analyzed in William Cronon, ed., *Uncommon Ground: Rethinking the Human Place in Nature* (New York: W. W. Norton, 1995). In this important volume, see esp. William Cronon, "The Trouble with Wilderness; or, Getting Back to the Wrong Nature," 69–90; and Jennifer Price, "Looking for Nature at the Mall: A Field Guide to the Nature Company," 186–203. Since *Uncommon Ground* appeared, examples of environmental histories that portray nature and culture as mutually constitutive abound. For examples, see Jennifer Price, *Flight Maps: Adventures with Nature in Modern America* (New York: Basic Books, 1999); Kathryn Morse, *The Nature of Gold: An Environmental History of the Klondike Gold Rush* (Seattle: University of Washington Press, 2003); Paul Sutter, *Driven Wild: How the Fight against Automobiles Launched the Modern Wilderness Movement* (Seattle: University of Washington Press, 2009); and the essays in Thomas Lekan and Thomas Zeller, eds., *Germany's Nature:*

Cultural Landscapes and Environmental History (New Brunswick, NJ: Rutgers University Press, 2005).

4. This research by environmental historians is vast. For overviews of the field, which include discussions of this sort of work, see Mart Stewart, "Environmental History: Profile of a Developing Field," *History Teacher* 31, no. 3 (May 1998): 351–368; J. R. McNeill, "The State of the Field of Environmental History," *Annual Review of Environment and Resources* 35 (Nov. 2010): 345–374.

5. For essays by environmental historians that call for this transnational approach, see Samuel Truett, "Neighbors by Nature: Rethinking Region, Nation, and Environmental History in the U.S.-MexicoBorderlands," *Environmental History* 2, no. 2 (Apr. 1997): 160–178; Paul Sutter, "Reflections: What Can U.S. Environmental Historians Learn from Non-U.S. Environmental Historiography?," *Environmental History* 18, no. 1 (Jan. 2003): 109–130; John McKenzie, "Empire and the Ecological Apocalypse: The Historiography of the Imperial Environment," in *Ecology and Empire: Environmental History of Settler Societies*, ed. Tom Griffiths and Libby Robin (Seattle: University of Washington Press, 1997), 215–228; Jeremy Adelman and Stephen Aron, "From Borderlands to Borders: Empires, Nation-States, and the Peoples in between in North American History," *American Historical Review* 104, no. 3 (June 1999): 814–841. For just a few examples of environmental historians tracking nature across national borders, see esp., Samuel Truett, *Fugitive Landscapes: The Forgotten History of the U.S.-Mexico Borderlands* (New Haven, CT: Yale University Press, 2008); Marc Cioc, *The Game of Conservation: International Treaties to Protect the World's Migratory Animals* (Athens: Ohio University Press, 2009); Mark Fiege, "The Weedy West: Mobile Nature, Boundaries, and Common Space in the Montana Landscape," *Western Historical Quarterly* 36 (Spring 2005): 22–47.

6. Donald Worster, "World without Borders: The Internationalizing of Environmental History," in "Papers from the First International Conference on Environmental History," special issue, *Environmental Review* 6, no. 2 (Autumn 1982): 8–13, at 13.

7. As the *Wall Street Journal* reported, "The earth resources program owes most of its technology to the highly classified military programs." William Burrows, "Sizing Up the Planet: Satellites Will Seek to Inventory Resources of Earth from Orbit," *Wall Street Journal*, June 8, 1970, 1. On the evolution of NASA technology from *TIROS* to *ATS* to *Landsat*, see Henry Hertzfeld and Ray Williamson, "The Social and Economic Impact of Earth Observing Satellites," in *Societal Impact of Spaceflight*, ed. Steven Dick and Roger Launius (Washington, DC: NASA Office of External Relations, History Division, 2007), 237–263. *Landsat* was originally called the *Earth Resources Technology Satellite* (*ERTS*).

8. United Press International, "NASA Satellite to Be Launched: 2d Earth Resources Craft to Relay Environmental Data," *New York Times*, Jan. 15, 1975, 53. See also *Photography from Space to Help Solve Problems on Earth: NASA*

Earth Resources Technology Satellite, 2, pamphlet published by NASA's Goddard Space Flight Center, ca. 1972, NASA Headquarters Archives, Washington, DC, NASA Historical Materials, folder 5745, ERTS Photos and Booklets.

9. M. Mitchel Waldrop, "Imaging the Earth (I): The Troubled First Decade of Landsat," *Science* 215 (Mar. 26, 1982): 1601.

10. Ibid.

11. "Ecological Surveys from Space," Office of Technological Utilization, NASA SP-230, 1970, NASA Headquarters Archives, NASA Historical Materials, folder 5754, Earth Resources Satellite, 1970; NASA, *Improving Our Environment* (Washington, DC: Government Printing Office, 1973); *Photography from Space to Help Solve Problems on Earth.*

12. Jeffrey St. John, "Space Effort: No Apologies Necessary," *Los Angeles Times*, Apr. 9, 1972, C3. See also "Space: Can NASA Keep Its Programs Aloft?," *BusinessWeek*, Feb. 13, 1971, 23.

13. NASA's budget during these years decreased from 3.9 to 3.2 billion dollars annually. For historical data on NASA's total budget for these years in both real and in 2008 inflation-adjusted dollars, see United States President, United States, and National Aeronautics and Space Council, *Aeronautics and Space Report of the President: Fiscal Year 2008 Activities* (Washington, DC: Government Printing Office, 2008), "Appendix D-1A: Space Activities of the U.S. Government, Historical Table of Budget Authority (in Millions of Real-Year Dollars)," 146, and "Appendix D-1B: Space Activities of the U.S. Government, Historical Table of Budget Authority (in Millions of Inflation-Adjusted FY 2008 Dollars)," 147.

14. On the economic benefits to American farmers of NASA's LACIE program, see Hertzfeld and Williamson, "Social and Economic Impact of Earth Observing Satellites," 240–241, 262. In the late 1970s the LACIE program was also used to forecast Soviet wheat supplies in an effort to avoid fluctuations in the international wheat market. On LACIE, see also "Landsat-2 Data Aid Research Management," *Bioscience* 25, no. 4 (Apr. 1975): 280. On the economic benefits for the United States of other satellite observations, see "Aerospace Research Profits Earth," *Roundup* (newspaper of the Johnson Space Center), Feb. 18, 1972, 2.

15. Between 1975 and 1980 Congress increased NASA's total budget from 3.22 to 5.24 billion dollars. When adjusted for inflation according to 2008 dollars, this represents an increase of 10 percent. For historical data on NASA's total budget in both real and inflation-adjusted dollars, see United States President, United States, and National Aeronautics and Space Council, *Aeronautics and Space Report of the President: Fiscal Year 2008 Activities*, 146, 147.

16. "Text of Address by President Nixon to General Assembly of the United Nations," *New York Times*, Sept. 19, 1969, 16.

17. "NASA Position Paper on the Remote Sensing of Planetary Surfaces

(Earth, Moon, Mars, Venus, etc.) from Orbital and Fly-by Spacecraft," paper attached to memorandum by NASA Advanced Missions Program Chief Peter Badgley, Oct. 8, 1965, box 075–14, series Apollo, Johnson Space Center History Collection, University of Houston at Clear Lake, Houston, TX.

18. For an example of this concern, see Edward Keating, "Hard Times: World Spy," *Ramparts* 9, no. 8 (Mar. 1971).

19. The proposal, which ultimately stalled in the UN's Scientific and Technical Sub-committee, was actually stricter than a similar UN proposal put forth by France and the Soviet Union the year before. On both these proposals, see Hamilton DeSassure, "Remote Sensing by Satellite: What Future for an International Regime?," *American Journal of International Law* 71, no. 4 (Oct. 1977): 714, 720. On *Landsat* possibly being used by developed countries to exploit natural resources in developing countries, see also John Hanessian, "International Aspects of Earth Resources Survey Satellite Programs," *Journal of the British Interplanetary Society* 23 (Spring 1970): 548.

20. "ERTS-EREP Proposal Review," memorandum by Verl Wilmarth to TA/Director of Science and Applications, July 7, 1971, record no. 14994, box 529, Johnson Space Center History Collection, University of Houston at Clear Lake.

21. On the lack of trained photointerpreters in the developing world, see Hanessian, "International Aspects of Earth Resources Survey Satellite Programs," 545. For additional concerns within NASA regarding a lack of skilled scientists in developing countries to take advantage of space technology, see "Practical Applications of Space Systems," 1975, NASA-CR-145434, National Academy of Sciences, Washington, DC.

22. For examples of these press releases by NASA, see "Earth Resources Experiments RFP," press release no. 70-117, July 14, 1970, NASA Headquarters Archives, NASA Historical Materials, folder 5754, Earth Resources Satellite, 1970; and "Skylab Experimenters Sought," press release no. 71-5, Jan. 19, 1971, record no. 142778, box 502, Johnson Space Center History Collection, University of Houston at Clear Lake.

23. In 1971 the UN created a Space Applications Program specifically to promote the use of Earth-observing remote-sensing data throughout the developing world. On the efforts of these international organizations to promote Earth-observing technology in developing countries, see V. Klemas and D. J. Leu, "Applicability of Spacecraft Remote Sensing to the Management of Food Resources in Developing Countries," Mar. 31, 1977, 31–48, Center for Remote Sensing, University of Delaware, report prepared for the School of Engineering and Applied Science, George Washington University, Washington, DC, and the Division of International Programs, National Science Foundation, Washington, DC.

24. On NASA's *Landsat* conference at the University of Michigan, see

"Earth Resources Survey Workshop," NASA press release no. 70-215, Dec. 23, 1970, NASA Headquarters Archives, NASA Historical Materials, folder 5754, Earth Resources Satellite, 1970. On the Johnson Space Center conference, see "All You Wanted to Know about Earth Resources," *Roundup* 14, no. 12 (June 6, 1975), 1. Lady Bird Johnson had NASA administrator Thomas Paine give a similar lecture on remote sensing of Earth resources at a cocktail party she threw for a group of foreign correspondents covering one of the early Apollo launches. On this cocktail party lecture, see oral interview of Dr. Thomas O. Paine by T. Harri Baker (tape 2), NASA Headquarters Archives, NASA Historical Materials, folder 4185, Paine Interviews Conducted by Baker, Lodsdon, Cohen, and Burke.

25. For a description of *Landsat* conferences in Ghana and Mali, see "Landsat May Help Bridge Technological Gap," *Roundup*, May 23, 1975, 2; "W. Africans Confer on Uses of Remote Sensing Data," *Roundup*, June 6, 1975, 2.

26. On similar *Landsat* conferences in the Philippines, see "Earth Resources Team Visits to the Philippines," Sept. 21, 1971, record no. 210333, report SRE, box 546, Johnson Space Center History Collection, University of Houston at Clear Lake. On efforts to promote *Landsat* across Latin America, see "Inter American Geodetic Survey Proposal for Multi-national ERTS (Earth Resources Technology Satellite) Cartographic Experiments," Apr. 7, 1972, record no. 213145, report IAGS-EROS, box 563, Johnson Space Center History Collection, University of Houston at Clear Lake.

27. On the expansion of NASA's international fellowship program to include study at US universities on *Landsat*, see John Hanessian Jr. and John Logsdon, "Earth Resources Technology Satellite: Securing International Participation," *Astronautics and Aeronautics*, Aug. 1970, 60.

28. On NASA's training of Brazilian and Mexican scientists and engineers at the Johnson Space Center, see Hanessian and Logsdon, "Earth Resources Technology Satellite," 59; Hanessian, "International Aspects of Earth Resources Survey Satellite Programs," 546. In this particular case the remote-sensing data was obtained from aircraft circling above those countries rather than from satellites.

29. "Landsat May Help Bridge Technological Gap," 2.

30. On NASA encouraging developing countries to build their own receiving stations, see Hertzfeld and Williamson, "Social and Economic Impact of Earth Observing Satellites," 239. On developing nations building *Landsat* receiving stations, see Klemas and Leu, "Applicability of Spacecraft Remote Sensing to the Management of Food Resources in Developing Countries," 42. On Zaire's *Landsat* receiving station in particular, see "Landsat May Help Bridge Technological Gap," 2.

31. "Landsat May Help Bridge Technological Gap," 2.

32. On this extensive use of *Landsat* data by fifty countries worldwide, see Klemas and Leu, "Applicability of Spacecraft Remote Sensing to the Management of Food Resources in Developing Countries," 41.

33. Allen L. Hammond, "Remote Sensing (I): Landsat Takes Hold in South America," *Science* 196, no. 4289 (Apr. 29, 1977): 511–512.

34. On material on NASA's use of *Landsat* in cooperation with the World Bank in Asia, see Klemas and Leu, "Applicability of Spacecraft Remote Sensing to the Management of Food Resources in Developing Countries," 35–36.

35. On *Landsat* data being applied to Sudan's Kordofan Province and Botswana's Okavango delta region, see Klemas and Leu, "Applicability of Spacecraft Remote Sensing to the Management of Food Resources in Developing Countries," 7, 33. On *Landsat* data being used for range management in Kenya, see "Landsat May Help Bridge Technological Gap," 2. For a list of African countries undertaking experiments with *Landsat* data, see Klemas and Leu, "Applicability of Spacecraft Remote Sensing to the Management of Food Resources in Developing Countries," 47.

36. For a description of *Landsat* data being used in Central and South America, see Klemas and Leu, "Applicability of Spacecraft Remote Sensing to the Management of Food Resources in Developing Countries," 31–48; Allen L. Hammond, "Remote Sensing (II): Brazil Explores Its Amazon Wilderness," *Science* 196, no. 4289 (Apr. 29, 1977): 513–515.

37. There is a rich literature on "natural" disasters within the field of environmental history. While the great majority of this scholarship accepts the unpredictability of these phenomena—from floods to wildfires to extreme weather such as hurricanes—it argues that the effects of such "natural" disasters are almost always dependent upon cultural and social practices. Here I am focusing on how these natural phenomena influenced both locals in the developing world (including scientists and government officials) and *Landsat*'s transnational technological network. For a sampling of this literature within environmental history, see Donald Worster, *Dust Bowl: The Southern Plains in the 1930s* (New York: Oxford University Press, 1979); Theodore Steinberg, *Acts of God: The Unnatural History of Natural Disasters in America* (New York: Oxford University Press, 2000); Christof Mauch and Christian Pfister, eds., *Natural Disasters, Cultural Responses: Case Studies toward a Global Environmental History* (New York: Lexington Books, 2009).

38. For a detailed discussion of the workshop hosted by the Malian government, see Brian Jirout, "One Satellite for the World: The American Landsat Earth Observation Satellite in Use, 1953–2008" (PhD diss., Georgia Institute of Technology, 2016), 139–143.

39. On NASA's *Landsat* program across the Sahel region of Africa, see Klemas and Leu, "Applicability of Spacecraft Remote Sensing to the Management of Food Resources in Developing Countries," 41; "Aid to W. Africa Aim of US Profs.," *Chicago Defender*, Sept. 8, 1973, 25.

40. Hammond, "Remote Sensing (I)," 512.

41. For a description of *Landsat* being used during these disasters, see

Charles J. Robinove, "Worldwide Disaster Warning and Assessment with Earth Resources Technology Satellites," in *Proceedings of the Tenth International Symposium on Remote Sensing of Environment*, Ann Arbor, MI, Oct. 6–10, 1975 (Ann Arbor: Environmental Research Institute of Michigan, University of Michigan, 1975), 2:811–820.

42. These quotations and a description of the various problems encountered by Brazilian technicians in creating the social networks necessary for *Landsat* to function properly in the country can be found in Hammond, "Remote Sensing (I)," 511–512. For a description of *Landsat* data being used in Central and South America, see Klemas and Leu, "Applicability of Spacecraft Remote Sensing to the Management of Food Resources in Developing Countries," 31–48; Hammond, "Remote Sensing (II)," 513–515.

43. These three maps are described in detail on pp. 1–6 of the Mekong Committee quarterly report cited in n. 1.

44. As quoted in Jeffrey W. Jacobs, "Mekong Committee History and Lessons for River Basin Development," *Geographical Journal* 161, no. 2 (July 1995): 142. Jacobs's article also describes the 1966 flood.

45. Mekong Committee Secretariat Willem J. van Liere, "Applications of Multispectral Photography to Water Resources Development Planning in the Lower Mekong Basin (Khmer Republic, Laos, Thailand and Viet-Nam," 76, Mar. 9, 1973, NASA Technical Report, Document ID 19730008739, Accession ID 73N17466, report no. E73-10257, PAPER-W3, NASA Headquarters Archives.

46. For a similar discussion of local indigenous people using *Landsat* data for their own purposes, see Karen Litfin, "The Gendered Eye in the Sky: A Feminist Perspective on Earth Observation Satellites," *Frontiers: A Journal of Women Studies*, Fall 1997, 41.

47. On NASA and the US government retaining ultimate control over *Landsat* experiments, see Hanessian, "International Aspects of Earth Resources Survey Satellite Programs," 552. In reviewing *Landsat* proposals from developing countries, NASA administrators were able to list an experiment as "N," meaning "Negotiation Required." Doing so gave NASA more control over the experiment being proposed. For an example of this process, see "Additional EREP Investigations," memorandum by NASA Associate Administrator for Applications Charles Mathews to Manned Spacecraft Center (Johnson Space Flight Center) Director Chris Kraft, Apr. 21, 1972, record no. 146924, box 535, Johnson Space Center Archives, University of Houston at Clear Lake.

48. My thinking here has been influenced by John Krige, *American Hegemony and the Postwar Reconstruction of Science in Europe* (Cambridge, MA: MIT Press, 2006), especially its introduction. For examples of the rich literature on coproduction within science studies, see Shelia Jasanoff, *States of Knowledge: The Co-production of Science and the Social Order* (London: Routledge, 2004).

49. This satellite data was compiled by both *Landsat 1* and *Landsat 2*. For

a description of this involvement by local scientists and government officials in corroborating *Landsat* data, see pp. 2–3 of "Annex II: Note on the Land Use Map of the Lower Mekong Basin" of the report cited in n. 1.

50. For references to "South Viet-Nam," see p. 2 of the report cited in n. 1. The *Landsat* map, which is titled "Landsat-2 Ground Track Coverage of Lower Mekong Basin," appears in the same publication on what is labeled by hand "5a," which is actually the eighth page of the report.

51. On the devastating impact of this ban on the Mekong Committee's *Landsat* work in Vietnam, see Jeffrey W. Jacobs, "The United States and the Mekong Project," *Water Policy* 1 (1998): 592.